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CHARACTERISTICS OF RESIDUES IN A BALLOON LOGGED AREA OF OLD-GROWTH DOUGLAS-FIR

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ABSTRACT

The volume and character of residues in a 44-acre old-growth Douglas-fir stand in the Oregon Cascades were determined before and after the area was clearcut and balloon logged.

The gross volume of residues on the ground increased from 5,585 cubic feet per acre before logging to 8,539 cubic feet after logging--a 53-percent increase. Not all size categories of residues increased in volume, however; a noticeable decrease was recorded in larger diameter classes, indicating some utilization of prelogging residues.

Usable residues are defined as material which can be yarded without breaking up, at least 10 percent sound 3 inches and greater in diameter, and at least 4 feet long. According to these specifications, more than 80 percent of the prelogging residues and nearly 70 percent of the logging residues could have been used.

Average soundness of the usable prelogging residues was 44 percent and 76 percent for the logging residues. A fourfold increase in piece count of these residues was recorded after logging. Most of this increase occurred in small diameter classes of residues.

More than half the usable residues was from felled trees. Bucked pieces were recorded with greater frequency in the postlogging residues than in the prelogging residues. Over 45 percent of the residues had been bucked. The larger and sounder portion could have been used if the bucking procedure had been modified.

KEYWORDS: Slash -)balloon logging, slash utilization, residue, wood waste utilization.

INTRODUCTION

The Pacific Northwest Forest and Range Experiment Station is conducting studies of three timber sale areas within the Pansy Creek drainage on the Estacada Ranger District of the Mount Hood National Forest in Oregon. These sales were designed to accomplish certain land management goals through use of three aerial logging systems--balloon, helicopter, and skyline. The aim of the studies is to evaluate the performance of the systems in attaining land management objectives. Aerial logging with balloon, helicopter, or skyline systems can substantially reduce the environmental impact of more conventional logging systems. The steep slopes, wet soil, streamside areas, fragile soils, and uneven terrain conditions in the sale areas all require special effort if merchantable timber is to be harvested without undesirable effects.

Residues left after logging are an important factor when the performance of the logging system in attaining land management objectives is evaluated. The land manager is faced with the problem of managing these residues to achieve optimum utilization of the resource, to minimize the risk of fire, and to achieve rapid regeneration in a manner that meets a wide range of environmental requirements for multiple-use forestry.

The aim of this report is to indicate the quantities and characteristics of residues left in an area logged by a balloon system. The main emphasis is on the utilization potential of the residues. The report is directed to those who are concerned with reducing logging residue to improve forest land management--either through removal for use as additional raw material or through onsite treatment.

SCOPE AND PROCEDURE

This report is based on an inventory of residues on a 44-acre area that was clearcut and logged by a balloon inverted skyline system.^{1/} The Forest Service timber sale contract specifications for the study area required that all logs one-third sound with a minimum net scale of 80 board feet be removed. These specifications were applicable only to logs 6 inches and larger in diameter and at least 8 feet long. Terrain on the study area was primarily steep and broken, with the slope varying from 10 to 90 percent. Old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) was the principal species in the timber stand (about 76 percent by volume). Secondary species included western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), western redcedar (*Thuja plicata* Donn), and noble fir (*Abies procera* Rehd.). The timber sale cruise estimated the average net merchantable stand volume to be about 43,000 board feet per acre.

Volume and character of the residue on the study area were determined before and after harvesting activities by a line intersect method of sampling.^{2/ 3/}

^{1/} Dykstra, Dennis P. 1974. The Pansy Basin study. Comparing yarding rates and costs for helicopter, balloon and cable systems. In *Loggers handbook*, vol. 34, p. 20-23, 158-164, 176-178. Pac. Logging Congr., Portland, Oreg.

^{2/} Warren, W. G., and P. F. Olsen. 1964. A line intersect technique for assessing logging waste. *For. Sci.* 10(3):267-276.

^{3/} Van Wagner, C. E. 1968. The line intersect method in forest fuel sampling. *For. Sci.* 14(1):20-26, illus.

Only material on the ground was recorded; standing (live or dead) material was not tallied. The residue remaining after logging was sampled before any slash disposal treatment. The line intersect method used a systematic grid-point sampling design, with random orientation of 200-foot line segments at each grid point.^{4/} Before and after logging, 80 line segments were located in the study area.

All residues 3 inches and greater in diameter at the point of intersection with the transect line were tallied. The 3-inch limit was based on what was considered to be a reasonable expected limit of utilization. Each piece was tallied by species, size, soundness, and material handling class. Diameter inside bark of each piece to the nearest inch at the point of crossing the transect line was recorded. Length (to a 3-inch diameter) to the nearest foot was recorded for all residue pieces 4 feet long or longer; a record of length for shorter pieces was not kept. Slabs from shattered trees were also recorded if the thickness plus width of the piece averaged 3 inches or greater; both thickness and width were recorded.

Soundness (proportion of wood usable for pulp chips--also known as firmwood) was recorded to the nearest 10 percent at the point of intersection. Estimates of soundness were based on the estimated proportion of the cross-sectional area that was sound and usable for pulp chips. Material decayed or excessively splintered was considered unusable. Where the cross-sectional area could not be seen, soundness at the transect point was estimated by viewing both ends of the piece.

In addition to records of coarse residues, a tally of the finer residues (fuels) was also made.^{5/} This tally included material from 0.26 to 1.0 inch in diameter in the first 6 feet of the transect line and 1.1 to 2.9 inches in diameter in the first 10 feet of the line.

During inventory of the logging residues, each piece of coarse residue was also classified into five material handling categories. Pieces too decayed, splintered, or short (less than 4 feet) to be considered usable were classed as fuel; all others were placed in one of the following categories:

1. From a felled tree and bucked on at least one end.
2. From a felled tree and broken on both ends.
3. From prelogging (natural) residue; i.e., from dead and down windthrows, etc., and bucked on at least one end.
4. From prelogging residue and broken on both ends.

^{4/} Howard, James O., and Franklin R. Ward. 1972. Measurement of logging residue--alternative applications of the line intersect method. USDA For. Serv. Res. Note PNW-183, 8 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

^{5/} Fosberg, Michael A., and John E. Deeming. 1971. Derivation of the 1- and 10-hour timelag fuel moisture calculations for fire-danger rating. USDA For. Serv. Res. Note RM-207, 8 p., illus. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

RESULTS

Logging Increased Residue Volume

The gross volume of all residues on the ground before logging averaged 5,585 cubic feet per acre. After logging, the volume estimate was 8,539 cubic feet per acre--a 53-percent increase. The volumes of residue before and after logging in various diameter classes are presented in table 1.

Table 1.--Average gross volume of residues before
and after logging, by diameter class,
Pansy Creek balloon logging sale

Diameter class (inches)	Gross volume of residues	
	Before logging ^{1/}	After logging ^{2/}
- -Cubic feet per acre- -		
0.26- 1.0	129.5	300.8
1.1 - 2.9	267.3	648.2
3.0 - 4.4	126.6	261.2
4.5 - 7.4	186.8	613.2
7.5 -10.4	363.3	700.7
10.5 -13.4	432.4	730.4
13.5 -16.4	360.5	821.2
16.5 -19.4	254.5	505.6
19.5 -22.4	529.2	757.2
22.5 -25.4	433.6	514.9
25.5 -28.4	300.8	674.7
28.5 -31.4	439.4	376.8
31.5 -34.4	185.6	275.3
34.5+	1,553.8	863.9
Slabs	22.2	494.6
Total	5,585.5	8,538.7

^{1/} Dead and down material which includes material not yardable, less than 10 percent sound, and less than 3 inches in diameter and 4 feet long.

^{2/} All down material which includes material not yardable, less than 10 percent sound, and less than 3 inches in diameter and 4 feet long.

The diameter classes of 28.5 to 31.4 inches and 34.5 inches and larger were exceptions to the general increase in residues volume. Utilization of the prelogging residues in these diameter classes apparently exceeded the volume generated in harvesting. This was especially true of the 34.5-inch and larger material.

The gross volume of logs removed during the balloon logging operation, as tallied at the truck scale station, was 9,825 cubic feet per acre. This is comparable to the volume of material 8,539 cubic feet, left on the ground as residue.

Utilization Potential of Residues

The portion of the total residue volume that has some potential for utilization is defined as material which can be yarded without breaking up and is at least 10 percent sound, 3 inches and greater in diameter, and at least 4 feet long. According to these specifications, 4,651 cubic feet per acre--about 80 percent of the prelogging residue--(coefficient of variation of 78.3 percent) could be utilized. A breakdown of this volume by diameter and length classes is contained in table 2. Some of these natural residues were salvaged during the harvesting operations. The marked reduction in the residue volume in the large size categories is due to utilization of the larger and sounder portions of the prelogging residues.

It should be noted that the harvesting activities reduced the utilization potential of the natural residues. Many pieces were broken and shattered when the standing trees were felled and yarded. The large increase in slab volume after logging (table 1) indicates considerable shattering occurred during the harvesting operations. About 90 percent of the slabs were not usable.

Much of the prelogging residue was defective. The average soundness of usable prelogging residues was 44 percent compared with 76 percent for logging residues. Removal of the larger and sounder prelogging residues during the logging operation reduced, to some extent, the average soundness of the logging residue. The species composition and soundness data of the usable residues before and after logging are presented in tables 3 and 4.

About 70 percent, or 5,974 cubic feet per acre (coefficient of variation of 55.2 percent) of the logging residues, had utilization potential according to the study specifications. The remaining 2,565 cubic feet of residue (difference between 8,539 (table 1) and 5,974 cubic feet per acre) did not meet these specifications. The average gross and net volumes of usable logging residue are shown by soundness and by diameter and length classes in table 5.

A fourfold increase in the usable residues piece-count per acre was recorded after logging. Most of this increase occurred in the small diameter classes of residue. The number of pieces of usable residue per acre before and after logging by soundness and by diameter and length classes is summarized in tables 6 and 7.

Logging residues that are at least 50 percent sound, 8 inches and greater in diameter, and at least 14 feet long averaged 2,815 cubic feet per acre and comprised almost half the usable residues. These residues would probably meet or exceed pulp or utility log specifications. This volume is in 103 pieces per acre, which is slightly less than 10 percent of the 1,077 pieces of residue on the average acre.

More than half the gross volume of usable logging residue was from felled trees. Of this amount, more than half had been bucked from longer pieces. For the previously down residue remaining on the logged area, less than half had been bucked from longer pieces. The volume of usable logging residue by soundness and material handling class is presented in table 8.

Over 45 percent of the usable residue volume was recorded as having been

Table 2.--Average gross and net volumes of usable prelogging residue
by diameter and length classes, Pansy Creek balloon logging
sale^{1/}

Diameter class (inches)	All classes		Length class (feet)							
			4.0-7.9		8.0-13.9		14.0-20.9		21.0+	
	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net
----- Cubic feet per acre -----										
3.0- 4.4	47.2	36.7	15.2	11.0	14.8	11.3	9.5	8.0	7.6	6.4
4.5- 7.4	141.2	99.7	10.8	4.4	34.1	21.8	27.0	19.7	69.2	53.8
7.5-10.4	323.4	199.4	43.0	19.7	25.1	12.4	73.6	28.7	181.6	138.6
10.5-13.4	365.2	190.2	27.6	1.0	21.9	12.8	86.4	34.2	229.3	142.2
13.5-16.4	294.6	174.6	10.6	6.4	11.9	1.2	71.6	28.2	200.5	138.8
16.5-19.4	254.5	132.8	22.6	0	22.6	3.0	89.9	42.2	119.4	87.6
19.5-22.4	446.7	186.3	9.4	5.6	41.2	12.4	97.7	31.3	298.4	137.0
22.5-25.4	433.6	190.0	26.8	1.4	42.6	8.3	70.6	21.1	293.6	159.2
25.5-28.4	227.6	98.5	0	0	36.6	11.0	52.4	8.9	138.8	78.6
28.5-31.4	355.5	99.3	42.0	8.4	84.0	13.6	63.0	23.1	166.6	54.2
31.5-34.4	185.6	64.9	0	0	27.0	10.8	0	0	158.7	54.1
34.5+	1,553.8	572.5	30.2	3.0	0	0	303.9	90.3	1,219.6	479.2
Slabs	22.2	2.3	3.2	.4	19.0	1.9	0	0	0	0
Total	4,651.1	2,047.2	241.4	61.3	380.8	120.5	945.6	335.7	3,083.3	1,529.7

^{1/} Includes all dead and down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, at least 10 percent sound, and yardable.

Table 3.--Average gross and net volumes of usable prelogging
residue by species, Pansy Creek balloon logging
sale^{1/}

Species	Gross volume	Net volume	Soundness	Proportion of total
	<i>Cubic feet per acre</i>		<i>- - - Percent - - -</i>	
Douglas-fir	2,256.2	821.0	36.4	48.5
Hemlock	1,173.2	520.2	44.3	25.2
Cedar	1,082.4	613.4	56.7	23.3
Pines	5.9	3.2	54.2	.1
Other softwoods	133.4	89.4	67.0	2.9
Hardwoods	0	--	--	--
Total or average	4,651.1	2,047.2	44.0	100.0

^{1/} Includes all dead and down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, at least 10 percent sound, and yardable.

Table 4.--Average gross and net volumes of usable logging residue by soundness and species, Paisy Creek balloon logging sale^{1/}

Percent soundness and species	Gross volume	Net volume	Soundness	Proportion of total
<i>Cubic feet per acre - - - - Percent - - - -</i>				
75+ percent sound:				
Douglas-fir	1,897.4	1,768.9	93.2	51.8
Hemlock	612.3	597.4	97.6	16.7
Cedar	1,096.2	1,053.6	96.1	30.0
Pines	23.5	23.5	100.0	.6
Other softwoods	27.8	27.8	100.0	.8
Hardwoods	1.7	1.7	100.0	0
Total or average	3,658.9	3,472.9	94.9	^{2/} 99.9
50+ percent sound:				
Douglas-fir	2,672.6	2,236.2	83.7	54.2
Hemlock	729.0	671.0	92.0	14.8
Cedar	1,453.0	1,281.5	88.2	29.4
Pines	49.0	38.2	78.0	1.0
Other softwoods	27.8	27.8	100.0	.6
Hardwoods	1.7	1.7	100.0	0
Total or average	4,933.1	4,256.4	86.3	100.0
30+ percent sound:				
Douglas-fir	3,054.9	2,370.6	77.6	55.6
Hemlock	773.9	687.4	88.8	14.1
Cedar	1,565.0	1,323.4	84.6	28.5
Pines	67.4	45.5	67.5	1.2
Other softwoods	27.8	27.8	100.0	.5
Hardwoods	1.7	1.7	100.0	0
Total or average	5,490.7	4,456.4	81.2	^{2/} 99.9
10+ percent sound:				
Douglas-fir	3,490.3	2,445.8	70.1	58.4
Hemlock	783.1	689.2	88.0	13.1
Cedar	1,591.4	1,328.4	83.5	26.6
Pines	78.0	47.6	61.0	1.3
Other softwoods	29.2	27.8	95.2	.5
Hardwoods	1.7	1.7	100.0	0
Total or average	5,973.7	4,540.5	76.0	^{2/} 99.9

^{1/} Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

^{2/} Total does not equal 100 because of rounding.

Table 5.--Average gross and net volumes of usable logging residue by soundness and by diameter and length classes, Pansy Creek balloon logging sale^{1/}

Percent soundness and diameter class (inches)	All classes		Length class (feet)							
			4.0-7.9		8.0-13.9		14.0-20.9		21.0+	
	Gross	Net	Gross	Net	Gross	Net	Gross	Net	Gross	Net
75+ percent sound:										
3.0- 4.4	235.6	232.2	102.3	100.4	67.7	66.8	42.2	42.1	23.3	22.8
4.5- 7.4	523.0	512.6	111.2	108.6	99.3	97.1	162.8	159.8	149.6	147.0
7.5-10.4	522.3	505.4	65.0	63.0	136.2	132.6	154.8	150.4	166.2	159.3
10.5-13.4	476.9	457.0	66.5	64.6	90.9	85.0	162.6	157.0	157.0	150.4
13.5-16.4	456.9	438.4	95.6	94.2	62.5	59.8	129.4	124.6	169.4	159.9
16.5-19.4	251.8	233.8	52.6	50.4	57.9	55.2	73.8	66.2	67.4	62.0
19.5-22.4	314.8	298.0	28.5	28.5	79.4	72.6	106.3	100.6	100.6	96.4
22.5-25.4	171.8	160.0	25.5	22.8	13.1	13.1	38.9	38.9	94.3	85.1
25.5-28.4	203.0	182.6	52.4	46.8	15.8	14.2	34.0	29.0	100.8	92.4
28.5-31.4	83.5	75.2	21.0	21.0	0	0	42.0	37.8	20.5	16.4
31.5-34.4	73.2	70.8	23.9	23.9	0	0	0	0	49.3	46.9
34.5+	321.2	283.4	110.7	101.9	0	0	58.3	52.5	152.2	129.0
Slabs	25.0	23.6	21.3	20.2	2.0	2.0	1.8	1.4	0	0
Total	3,659.0	3,473.0	776.5	746.3	624.8	598.4	1,006.9	960.3	1,250.6	1,167.6
50+ percent sound:										
3.0- 4.4	248.5	240.2	108.6	104.2	71.3	69.1	43.7	43.0	24.8	23.8
4.5- 7.4	563.2	537.6	125.0	116.8	103.5	99.6	175.6	167.8	159.2	153.4
7.5-10.4	582.4	542.4	71.3	67.0	148.1	140.0	169.8	159.8	193.0	175.6
10.5-13.4	570.0	515.6	73.6	69.0	107.8	95.6	189.8	173.3	198.8	177.8
13.5-16.4	591.2	524.4	104.8	100.1	90.9	76.9	165.0	148.0	230.5	199.3
16.5-19.4	354.0	294.3	76.6	65.6	64.5	59.2	89.6	74.8	123.2	94.7
19.5-22.4	494.2	409.8	61.4	50.4	110.8	91.4	134.1	118.1	188.0	149.9
22.5-25.4	290.6	232.6	52.4	38.9	38.8	31.2	65.8	55.0	133.6	107.4
25.5-28.4	370.3	279.9	52.4	46.8	32.8	22.7	83.4	57.1	201.8	153.1
28.5-31.4	189.3	141.0	21.0	21.0	0	0	42.0	37.8	126.4	82.2
31.5-34.4	168.1	132.6	23.9	23.9	23.3	14.0	0	0	121.0	94.6
34.5+	469.4	372.2	110.7	101.9	0	0	87.8	73.2	271.0	197.2
Slabs	41.8	33.6	30.4	25.4	4.8	3.9	6.5	4.2	0	0
Total	4,933.0	4,256.2	912.1	831.0	796.6	703.6	1,253.1	1,112.1	1,971.3	1,609.0
30+ percent sound:										
3.0- 4.4	250.6	241.1	110.4	105.0	71.6	69.2	43.9	43.1	24.8	23.8
4.5- 7.4	575.0	541.8	130.3	118.6	106.8	100.9	177.5	168.6	160.4	153.7
7.5-10.4	614.7	554.0	75.0	68.2	154.7	142.2	177.0	162.2	208.0	181.4
10.5-13.4	598.0	525.4	76.4	69.8	107.8	95.6	203.0	178.2	211.0	181.8
13.5-16.4	640.8	541.8	104.8	100.1	111.8	84.2	183.2	154.0	240.9	203.4
16.5-19.4	389.4	306.4	76.6	65.6	71.8	61.4	97.0	77.0	144.0	102.4
19.5-22.4	607.0	449.6	61.4	50.4	131.2	98.5	176.7	134.1	237.7	166.7
22.5-25.4	370.6	259.2	52.4	38.9	52.3	35.2	118.8	72.3	147.0	112.8
25.5-28.4	437.6	306.8	52.4	46.8	48.6	29.0	119.6	71.6	217.2	159.4
28.5-31.4	272.8	170.3	42.0	27.3	0	0	42.0	37.8	188.8	105.2
31.5-34.4	222.0	154.1	23.9	23.9	23.3	14.0	0	0	174.8	116.2
34.5+	469.4	372.2	110.7	101.9	0	0	87.8	73.2	271.0	197.2
Slabs	42.6	33.9	31.4	25.7	4.8	3.9	6.5	4.2	0	0
Total	5,490.5	4,456.6	947.7	842.2	884.7	734.1	1,433.0	1,176.3	2,225.6	1,704.0
10+ percent sound:										
3.0- 4.4	253.0	241.4	111.9	105.2	71.7	69.2	44.4	43.2	24.8	23.8
4.5- 7.4	582.4	542.8	132.8	119.0	108.2	101.2	181.0	169.0	160.4	153.7
7.5-10.4	633.6	557.0	83.6	69.4	156.6	142.6	181.2	162.8	212.2	182.2
10.5-13.4	633.2	530.3	83.6	70.8	114.0	96.2	210.8	179.8	224.8	183.4
13.5-16.4	695.4	550.6	115.2	101.6	120.9	85.0	192.4	155.8	267.0	208.2
16.5-19.4	432.6	313.4	83.2	66.9	79.2	62.8	103.6	78.4	166.6	105.4
19.5-22.4	629.5	454.2	61.4	50.4	131.2	98.5	176.7	134.1	260.2	171.2
22.5-25.4	396.3	261.8	52.4	38.9	52.3	35.2	132.3	73.6	159.4	114.0
25.5-28.4	508.2	321.0	68.1	50.0	48.6	29.0	137.8	75.2	253.7	166.7
28.5-31.4	272.8	170.3	42.0	27.3	0	0	42.0	37.8	188.8	105.2
31.5-34.4	275.3	164.8	23.9	23.9	23.3	14.0	0	0	228.2	126.9
34.5+	607.2	396.8	110.7	101.9	0	0	125.2	80.6	371.4	214.4
Slabs	54.0	36.1	33.0	26.0	4.8	3.9	16.1	6.2	0	0
Total	5,973.5	4,540.5	1,001.8	851.3	910.8	737.6	1,543.5	1,196.5	2,517.5	1,755.1

^{1/} Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

Table 6.--Average number of pieces per acre of usable prelogging residue by diameter and length classes, Pansy Creek balloon logging sale^{1/}

Diameter class (inches)	All classes	Length class (feet)			
		4.0-7.9	8.0-13.9	14.0-20.9	21.0+
3.0- 4.4	70.5	39.5	20.0	7.5	4.0
4.5- 7.4	51.0	12.0	17.0	9.0	13.5
7.5-10.4	49.0	17.5	5.5	9.5	16.0
10.5-13.4	28.5	6.0	3.0	7.0	12.5
13.5-16.4	12.5	1.5	1.0	3.5	7.0
16.5-19.4	9.5	2.5	1.0	3.5	3.0
19.5-22.4	9.5	1.0	1.5	2.5	5.0
22.5-25.4	7.5	1.5	1.5	1.5	3.5
25.5-28.4	3.0	0	1.0	1.0	1.5
28.5-31.4	5.5	1.5	1.5	1.0	1.0
31.5-34.4	1.0	0	.5	0	1.0
34.5+	8.5	1.0	0	2.5	5.0
Slabs	3.0	2.5	.5	0	0
Total	259.0	86.5	54.0	48.5	73.0

^{1/} Includes all dead and down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, at least 10 percent sound, and yardable.

Table 8.--Average gross and net volumes of usable logging residue by soundness and material handling class, Pansy Creek balloon logging sale^{1/}

Percent soundness and material handling class	Gross volume	Net volume	Soundness	Proportion of total
-Cubic feet per acre- - - - Percent - - - -				
75+ percent sound:				
Felled and bucked	1,376.1	1,352.0	98.2	37.6
Felled and broken	1,237.4	1,196.4	96.7	33.8
Down and bucked	419.5	370.6	88.3	11.5
Down and broken	625.8	553.7	88.5	17.1
Total	3,658.8	3,472.7	94.9	100.0
50+ percent sound:				
Felled and bucked	1,500.6	1,431.3	95.4	30.4
Felled and broken	1,390.8	1,290.6	92.8	28.2
Down and bucked	832.0	629.6	75.7	16.9
Down and broken	1,209.6	904.8	74.8	24.5
Total	4,933.0	4,256.3	86.3	100.0
30+ percent sound:				
Felled and bucked	1,532.8	1,443.4	94.2	27.9
Felled and broken	1,434.4	1,307.6	91.2	26.1
Down and bucked	979.4	678.2	69.2	17.8
Down and broken	1,544.4	1,027.3	66.5	28.1
Total	5,491.0	4,456.5	81.2	^{2/} 99.9
10+ percent sound:				
Felled and bucked	1,610.5	1,457.4	90.5	27.0
Felled and broken	1,503.6	1,315.7	87.5	25.2
Down and bucked	1,123.6	705.8	62.8	18.8
Down and broken	1,736.0	1,061.6	61.2	29.1
Total	5,973.7	4,540.5	76.0	^{2/} 100.1

^{1/} Includes all down material averaging at least 3.0 inches in diameter (inside bark) and 4.0 feet long, and yardable.

^{2/} Total does not equal 100 because of rounding.

bucked from larger pieces (i.e., felled and bucked plus down and bucked classes, (table 8)). A portion of this volume might have been salvaged with an alternative bucking procedure. Such a procedure would minimize the amount of tree bole residue left on the area by limiting long butting and bucking out of defective segments and broken log ends. This material would then be yarded with the merchantable portion of the logs.

CONCLUDING REMARKS

Information contained in this report was obtained from a clearcut, balloon logged area. Comparable information from areas logged by helicopter and skyline systems is nearing completion. Results from these studies will be reported in separate papers.

Since the present investigation is only a case study, results are not necessarily indicative of other balloon logging operations. Still, the information presented can be used by forest managers, who are continually confronted with the problems of residue production, its reduction, and evaluation of the characteristics, volumes, and potential uses of the residues generated. It provides some indication of the fuel loading that can be expected from similar harvesting operations. It further provides a basis for evaluating the effects of changes in utilization either from changes in the market or in contractual requirements such as required yarding of unutilized material (YUM).

Results of this study strongly suggest that a substantial volume of usable residues can be salvaged by modifying bucking practices. This is particularly feasible where a defective but usable portion of the bole is left attached and removed with the more merchantable portion of the stem.

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METRIC CONVERSIONS

1 hectare = 2.471 05 acres

1 cubic foot per acre = 0.069 972 5 cubic meter/hectare

1 inch = 2.54 centimeters

1 foot = 0.304 8 meter

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

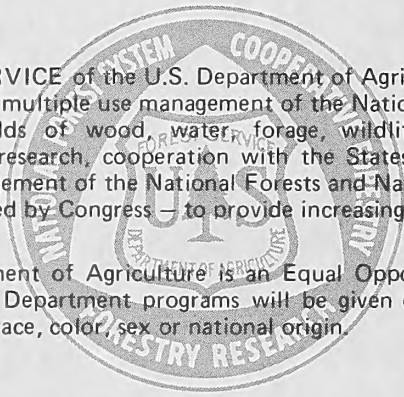
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